Sugar Platform Partnership Development

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Abstract

The partnership development program of the sugar platform becomes more vital as the processes move closer to commercial viability. Through recent colloquies and meetings, industrial partners have provided valuable insight to DOE and NREL on how to structure planned cost-shared technology pilot scale demonstrations, leading to the highly successful DOE 2002 Biomass R&D solicitation that resulted in six awards with nearly $80 million in industrial cost-share.

The partnership development team also undertook a major market study to enumerate and analyze the political and environmental conditions that are changing U.S. ethanol markets, the range of projected demand levels 2003 – 2012, and predictions of price ranges due to changing markets. This study set out to answer four fundamental questions:

- What will be the range of estimated U.S. ethanol consumption in the 2004 – 2012 time period under different economic assumptions?
- How will future U.S. ethanol consumption be affected by proposed state and federal legislative mandates, such at the phase-out of MTBE and/or the passage of a Renewable Fuels Standards (RFS)?
- What will be estimated future market prices for ethanol under a range of consumption and political scenarios?
- How will changes within or external to the corn ethanol industry affect the price and availability of ethanol?

U.S. production and consumption of ethanol is expected to rise sharply in the period 2004 – 2012, reaching nearly 4 billion gallons/year by 2007 and 5 billion gallons by 2012. This sharp increase in demand is driven primarily by the planned phaseout of MTBE in major gasoline markets and secondarily by the possible passage by Congress of the Renewable Fuels Standard (RFS). This sharp increase in demand will provide upward pressure on ethanol prices, with consensus estimates being that ethanol prices will reach $1.50/gallon by 2006 – 2010 (depending on assumptions on market demand, as well as state and local mandates). Rising ethanol production levels will in turn put upward pressure on corn prices, with even the most optimistic estimates see corn prices rising from $2.10 – 2.20/bushel today to $2.60 – $3.00 within ten years.

The proposed phase out of MTBE by itself will put sharp upward pressure on grain-based ethanol prices in the period 2003 – 2006 while new ethanol production capacity is being built. The higher predicted market prices for ethanol and corn will make the business case for cellulosic ethanol much more attractive throughout the whole period 2004 –2012. High ethanol prices, rising corn prices and surging DDG production may also encourage grain ethanol producers to experiment in the near-term with the addition of significant cellulosic biomass conversion trains at existing or new dry mill facilities, using DDG as the feedstock**.** Extracting the cellulosic and hemi-cellulosic fractions from the DDG should significantly upgrade the protein content and food value of the resulting animal feed, making it more valuable and suitable

for market segments such as poultry and swine feeding. Similarly, wet millers may want to co-locate a small cellulosic biomass production facility at an existing ethanol plant, using feedstocks such as corn fiber or soy hulls to produce additional ethanol.

The emergence of the biorefinery and new biomass processing industries will require new set of tools and analytic methods. NREL and DOE/OBP are considering ways to provide immediate support to firms entering these market segments, primarily through mechanisms such as the proposed Biomass Rapid Analysis Network (BRAN), which would provide such needed support as 2 and 5 day training programs; development of standard data collection and analysis protocols; creation of new multivariate analysis equations; sample preparation; data clearinghouse for BRAN members; software testing; and equipment testing.

Introduction

As Sugar Platform projects moves forward toward commercialization, the need for industrial partners increases. Industrial partners will provide vital expertise for reducing capital and operating costs to the levels needed to make worthwhile the capital investment for the first large-scale plants. Industrial partners will also identify the slate of feedstocks and end-use products for the scaled-up Sugar Platform conversion process. Also, industrial partners will bear most of the substantial financial investment cost in the first commercial-scale plants that will convert lignocellulosic feedstocks to fuels, chemicals, and value-added products.

As the Sugar Platform processes become better defined and optimized, industrial partners will also provide NREL and DOE the detailed knowledge of potential markets and product prices needed for technology scale-up and commercialization. In order to meet the financial returns required by lenders, ESP may need a team of industrial partners, each dealing with specialized high-value product streams and market niches.

Recent Sugar Platform Industrial Partnership Background

The NREL Sugar Platform has had a very successful program of industrial collaboration and partnership over the past two years. Starting in late 2001, the NREL Sugar Platform held a series of day-long colloquies with representatives of industries that will be crucial to the ultimate commercialization of lignocellulosic biomass conversion: industries such as chemicals, biotechnology, enzyme production, food processing, and ethanol production. These colloquies provided not only valuable industrial input into the direction of the research effort, but also gave detailed knowledge of Sugar Platform team members to leading firms in key industries.

The 2001 industrial colloquy participants provided invaluable feedback on how NREL and DOE were planning to structure the future Sugar Platform technology commercialization process. In particular, industrial reviewers indicated that projected rate of return from ethanol from purchased corn stover still is not sufficient to justify the levels of capital investment that would be required. They suggested that the Biomass Program consider looking for more valuable mix of products and/or consider the use of low cost or no cost feedstocks for the first commercial-scale plants. They also suggested that cellulosic-based ethanol production might be more economic, in the near-term, if it could be added to existing ethanol plants or food processing facilities.

This feedback from industrial colloquy participants was incorporated into the 2002 Biomass Research & Development Solicitation that the DOE Office of Biomass Programs released in April 2002. Industrial firms were allowed to select their preferred biomass feedstock, the slate of products that the pilot plant would produce, and the preferred conversion process for transforming biomass to fuels, chemicals, or value-added products. This flexibility proved to very attractive to potential industrial partners, even though the DOE solicitation required a 50% cost-share, with 129 groups submitting preliminary pre-proposals and 29 groups submitting full cost-shared proposals. Competing teams included leading chemical producers, ethanol producers, food processors, enzyme firms, and biomass polymer firms. Three of the winning

industrial firms included NREL as a partner in the research and development that would lead to a pilot plant in 3 – 4 years.

This expression of industrial interest in Sugar Platform partnerships was despite great uncertainty about the future demand and pricing for ethanol. Projections of the expansion of U.S. ethanol production over the period 2002 – 2012 vary widely, due to uncertainties about the phase-out of MTBE as a gasoline additive, future ethanol tax exemptions, and legislative mandates for renewable fuels content in transportation fuels.

New FY03 – FY07 Sugar Platform Partnerships

As proof of the increasing private sector interest in the sugar platform, DOE/OBP received an overwhelming response to its request for cost-shared project proposals under its 2002 Biomass R&D solicitation. More than 125 consortia expressed formal interest in the preproposal stage, and DOE asked 30 of those groups to submit full proposals. Out of that group, DOE chose six groups to move to award negotiation. The level of interest in the biorefinery concept is shown by the total amount of industrial cost shares for these six projects, which is approximately $80 million. These projects are scheduled to last 3 – 4 years and involve testing of the various biorefinery concepts through the pilot scale stage.

High Plains Corporation -- Advanced Biorefining of Distiller's Grain and Corn Stover Blends: Pre -Commercialization of a Biomass-Derived Process Technology

High Plains Corporation (HPC), in collaboration with Novozymes North America, Inc. (NZNA), VTT-Finland (VTT) and the National Renewable Energy Laboratory (NREL), will develop a novel biomass-derived process technology that utilizes advanced biorefined Distiller's Grain (DG) and Corn Stover (CS) blends to achieve significantly higher ethanol yields while maintaining the protein feed value. This technology will enable a more economical, sustainable industry; reduce petroleum use per ethanol gallon produced; and increase the availability of ethanol. The project will demonstrate at bench and pilot scale, a viable pretreatment process for DG and CS to convert residual starch, cellulose and hemicellulose to ethanol and high-protein feed. Bench-scale and small pilot-scale process analysis will undergo Stage Gate economic criteria for advancement into large pilot-scale integration. The bench and small pilot scale phases of the project will be performed at the NREL and NZNA facilities. Final integration of the large-scale pilot facilities will occur at the High Plains York, Nebraska (HPY) plant, a 50 million gallon per year corn dry- mill plant.

Broin & Associates: A Second Generation Dry Mill Biorefinery

Broin and Associates, Inc. will work in cooperation with DOE in a joint project to research and develop a dry mill "Biorefinery" process for enhancing the economics of existing ethanol dry mills by creating additional co-products and increasing ethanol yields. In this "2nd Generation" dry mill, Broin will fractionate the bran, germ, and endosperm in the incoming corn feed using proprietary processes and equipment. This revolutionary mechanical separation will enable flexibility in feedstock utilization,

substrate conversion, and fermentation process, while expanding options for value added co-product production. With the assistance of the National Renewable Energy Laboratory (NREL), Broin will investigate at bench and pilot-scale the technical and economic feasibility of converting the hemi-cellulosic and cellulosic fractions of the extracted corn bran to ethanol as well as upgrading the bran and endosperm fermentation residues to high protein animal feeds.

A New Biorefinery Platform Intermediate

Cargill, through collaboration with their partners Codexis, Inc. and Pacific Northwest National Laboratory (PNNL), will develop, a new bio-based platform technology to produce a portfolio of products based on 3-hydroxypropionic acid (3-HP) produced by the fermentation of carbohydrates. For the first step, Codexis, a subsidiary of Maxygen, Inc., and a leader in DNA evolution technology, will optimize the genes and pathway for production of 3-HP. Cargill will then optimize the organism and fermentation process. For the second step, Cargill will partner with the Chemical Process Development Group at PNNL to screen catalysts and develop process flowsheets, simulations, and economic estimates for a number of 3-HP derivatives. This project will deliver an organism and process for 3-HP production, and catalysts and complete process concepts suitable for piloting and scale-up for industrial production.

Making Industrial Bio-refining Happen

Cargill Dow in partnership with Iogen, Shell Global Solutions, and CNH Global NV (CNH) will develop and pilot-scale a demonstration biorefinery project in collaboration with wheat, corn, and rice grower organizations, national labs, and universities, as well as environmental and social non-government organizations. The project focuses on process and fermentation technologies as these will constitute the "heart" of the economically and environmentally sound biorefinery of the future. The Cargill Dow team is taking a unique and long-overdue approach by allocating over 25% of the proposed research budget to agricultural process systems and integration of biomass technologies into the agriculture community. This project will for the first time bring all of the players required for successful commercialization of the lignocellulosic biorefinery concept into an integrated focused effort. The major goals of the project are to develop and validate process technology and sustainable agricultural systems that will cost effectively produce sugars and chemicals such as lactic acid and ethanol from lignocellulosic biomass; and Ensure that growers and grower organizations have a first opportunity to participate in the commercial development of the resulting biorefinery technology.

Integrated Corn-Based Bio Refinery (ICBR) Project

DuPont will work in cooperation with DOE in a joint project to build a bio-based production facility. The plant will utilize new technology to convert corn and stover into fermentable sugars for parallel production of added value chemicals. DuPont will collaborate with Diversa and the National Renewable Energy Laboratory (NREL) on the project.

Separation of Corn Fiber and Conversion to Fuels and Chemicals Phase II: Pilot - scale Operation

Under a current DOE/EE/OTT sponsored project entitled Corn Fiber Separations and Conversion to Fuels and Chemicals, bench-scale testing has lead to the development of a technically and economically feasible integrated process for recovery of the hemicellulose, protein and oil components from corn fiber and subsequent conversion of these components to value-added products. Under this new project, the National Corn Growers Association (NCGA) will lead a team to conduct pilot-scale testing to validate the process prior to full-scale commercial implementation. The project team is multidisciplinary, with business managers, engineers, chemists, and biochemists from Archer Daniels Midland (ADM), and Pacific Northwest National Laboratory (PNNL) joining NCGA for the effort.

Changing Ethanol Markets and Prices

Because of the importance of future ethanol market sizes and prices on the economic viability of proposed cellulosic biorefineries, Sugar Platform management asked the Sugar Platform partnership development team to look at the political and environmental conditions that are changing U.S. ethanol markets, the range of projected demand levels 2003 – 2012, and predictions of price ranges due to changing markets. The partnership development team collected both primary and secondary data on changes in the ethanol industry, recent crop and fuel production as well as full range of projections by U.S. DOE, USDA, and third party analysts on trends in prices and consumption for ethanol (and key ethanol feedstock grains) covering the period 2002 – 2012. There are four fundamental questions that the resulting market assessment addressed as we examine the potential future market for cellulosic ethanol in the period 2004 - 2012:

- What will be the range of estimated U.S. ethanol consumption in the 2004 – 2012 time period under different economic assumptions?
- How will future U.S. ethanol consumption be affected by proposed state and federal legislative mandates, such at the phase-out of MTBE and/or the passage of a Renewable Fuels Standards (RFS)?
- What will be estimated future market prices for ethanol under a range of consumption and political scenarios?
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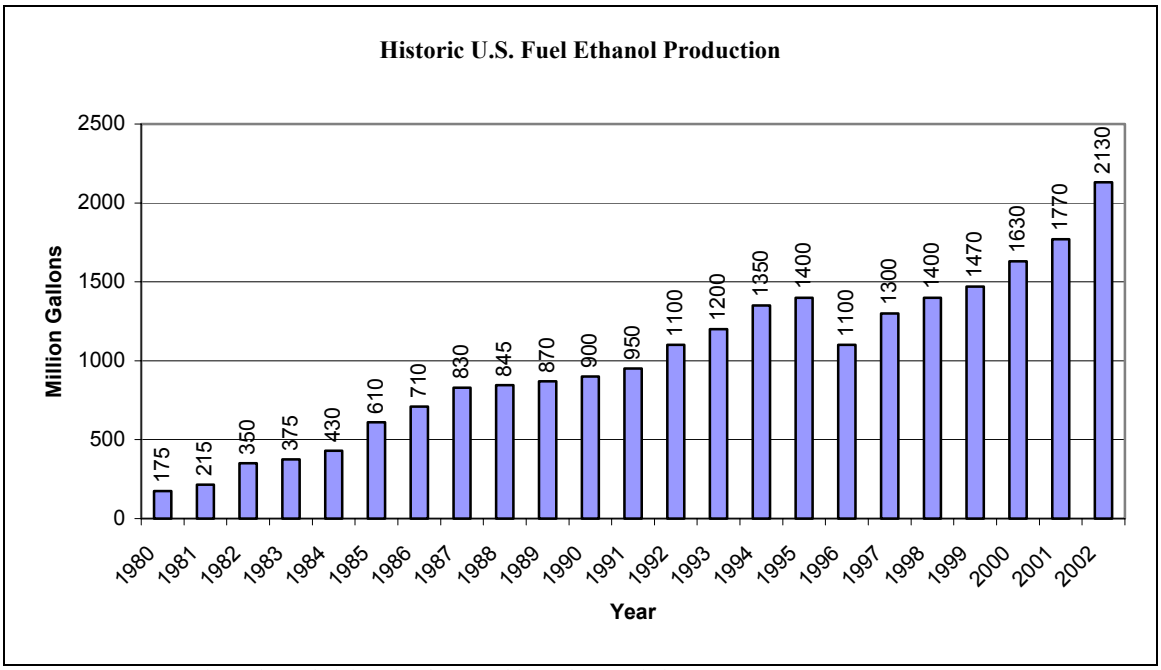
Recent Ethanol Production and Price Trends

The U.S. grain ethanol industry has undergone a remarkable transformation in the past 25 years, moving from annual output of less than 20 million gallons a year in the late 1970s to output approaching 2 billion gallons per year in 2002 (see Figure 1 below). This growth has been fueled by the phase-out of lead additives in gasoline, federal gasoline tax exemptions, state ethanol

production incentives, and federal oxygenated and reformulated gasoline (RFG) mandates in key urban areas.

Figure 1: Ethanol Production Trends



Source: U.S. Energy Information Administration / Renewable Fuels Association

As ethanol has moved from a gasoline stock extender to a key regional gasoline blending component, its wholesale price has become linked to the price of gasoline rather than to the price of its key feedstock, corn. In recent years, ample corn supplies and the resulting low corn prices have helped make grain-based ethanol production quite profitable. The only exception, the drought-induced doubling of corn prices in mid-1996, led many less efficient privately owned dry mills to cut back or stop ethanol production.

In the early years of the U.S. ethanol industry, much of the installed ethanol production capacity was in wet mills, large facilities that used relatively capital-intensive technology to produce a range of valuable products (corn oil, corn gluten feed, corn germ, and corn gluten meal) in addition to ethanol. In the past decade, however, most new U.S. ethanol production capacity has been created in the form of dry mills, which use less capital-intensive technologies to produce ethanol and an animal feed co-product called distiller's dried grain (DDG). Dry mills can be built quickly, are relatively simple to operate, and have front-end capital requirements which are only half those of wet mills. In the past decade, many of the dry mills were created as limited liability partnerships owned primarily by farmer cooperatives. Early dry mills were often small operations, capable of producing 10 – 15 million gallons of ethanol per year and marketing their DDG locally to neighboring farms or cooperative members. Today, new modern dry mills are much larger and much more efficient, with annual production of 40 – 45 million gallons per year.

The construction of new dry mills since 1995 has been concentrated in four states: Minnesota, South Dakota, Iowa, and Nebraska. This is due to a variety of factors: state ethanol production

incentives, ready availability of corn, farmer willingness to invest in plant equity, and state promotion of farmer cooperative enterprises.

Current Initiatives and Regulatory Changes that may Affect Future Grain and Cellulosic Ethanol Plant Construction

There are several major federal and state public policy initiatives currently underway that may drastically affect the demand and price for ethanol in the United States. The two chief initiatives are contained in pending federal energy legislation: **the renewable fuels standard** (RFS) and the **phase-out of MTBE[1] as a gasoline additive.** The renewable fuels standard, as proposed in the Senate version of the 2002 energy bill, will require 2.3 billion gallons of renewable fuel as part of the U.S. transportation fuel pool, starting in 2004, with the mandated renewable fuel component rising incrementally to 5.0 billion gallons by 2012 (see table 1 below). As of mid-March, 2003, the Renewable Fuels Standard was a matter of great controversy among both House and Senate members, and its inclusion in the 2003 Energy bill is still in doubt.

Table 1 – Renewable Fuels Standard

Senate Renewable Fuels Standard Schedule as of 02/01/2003									
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Billion gallons per year	2.3	2.6	2.9	3.2	3.5	3.9	4.3	4.7	5.0

Prepared by BBI International.

The phase-out of MTBE is both a state and federal initiative. 14 states have already banned or limited use of MTBE in gasoline blending, with the most important of these being California (followed by New York, Michigan, and Ohio). The California MTBE ban is effective the last day of 2003. Pending federal legislation would ban MTBE within four years (although giving states some discretion to allow continued MTBE blending into gasoline at relatively low levels).

Coupled with the RFS and the MTBE phase out is a proposed major adjustment in the federally mandated reformulated gasoline program – **the elimination of the 2.0% oxygenate mandate in gasoline for urban areas not in compliance with federal ozone standards.** This change will give petroleum refiners more flexibility in gasoline blending and will eliminate some "boutique gasolines" that are only used in a small geographical area.

Lastly, the EPA has been finalizing new standards for sharp reductions in the sulfur content in gasoline and diesel fuel. While the desulfurization push does not directly affect ethanol usage, it will require a very large infusion of new capital investment, which may reduce the availability of capital for other fuels investments such as cellulosic ethanol plants.

Projected Ethanol Production and Price Projections 2003 – 2010

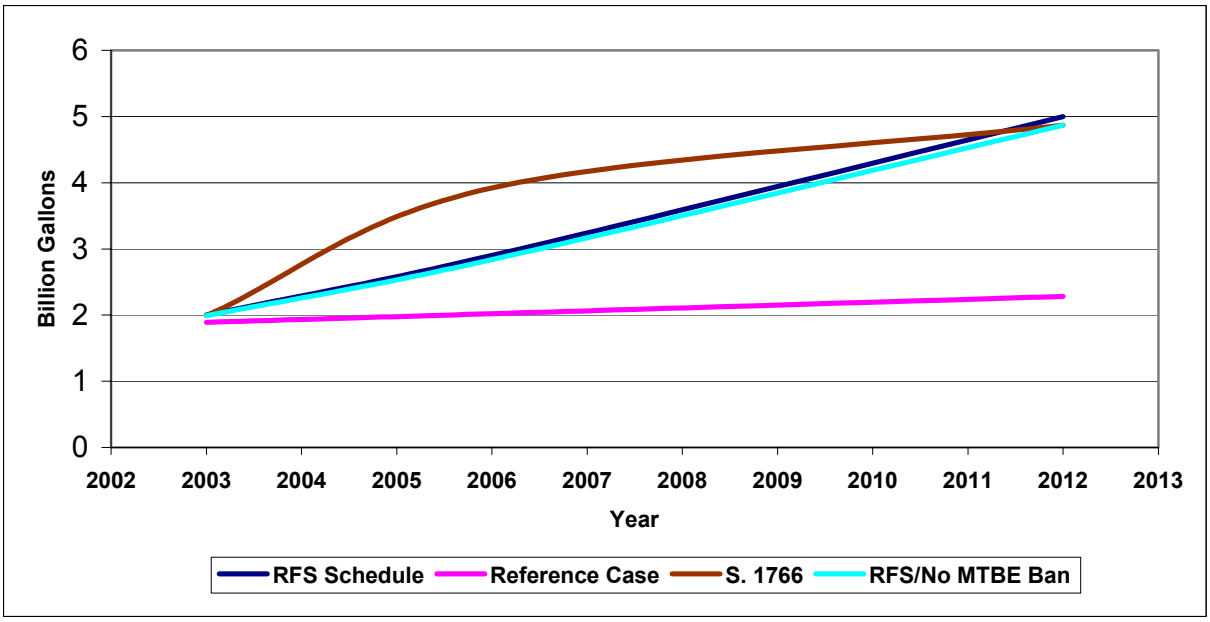
[1] MTBE is methyl tertiary-butyl ether, commonly blended into gasoline to provide oxygen and octane in EPA designated non-attainment areas requiring reformulated gasoline and oxygenated fuels.

A number of recent studies and analyses have been undertaken of the proposed Renewable Fuels Standard and the phase-out of MTBE, examining the impacts of these initiatives on the gasoline supply, demand for ethanol, future prices for ethanol and corn, and politically important variables such as rural income levels. While the assumptions underlying the various studies vary considerably, there is a consensus on the direction of the impacts in the next decade and on the upper and lower limits of range of results.

Levels of Ethanol Consumption

U.S. ethanol production is expected to ramp up sharply from 2002's 2.130 billion gallons, (see figured 2) initially just to meet the demand created by the phase-out of MTBE in

Figure 2: Renewable Fuel Production 2003 – 2012
Under various Potential Scenarios



Source: Prepared by EIA, March 2002

California at the end of 2003 (see figure 2). California is the largest U.S. gasoline market, with 2002 gasoline consumption estimated to be 1.181 million barrels (46.96 million gallons) per day. 79% or 935,000 barrels per day of that gasoline is reformulated gasoline. The removal of MTBE from California RFG would eliminate approximately 7.7 – 8.6% of the California gasoline pool. Just replacing the oxygen content lost (not the total volume) by the elimination of MTBE in California will require an **additional** 650 - 850 million gallons of ethanol in 2004

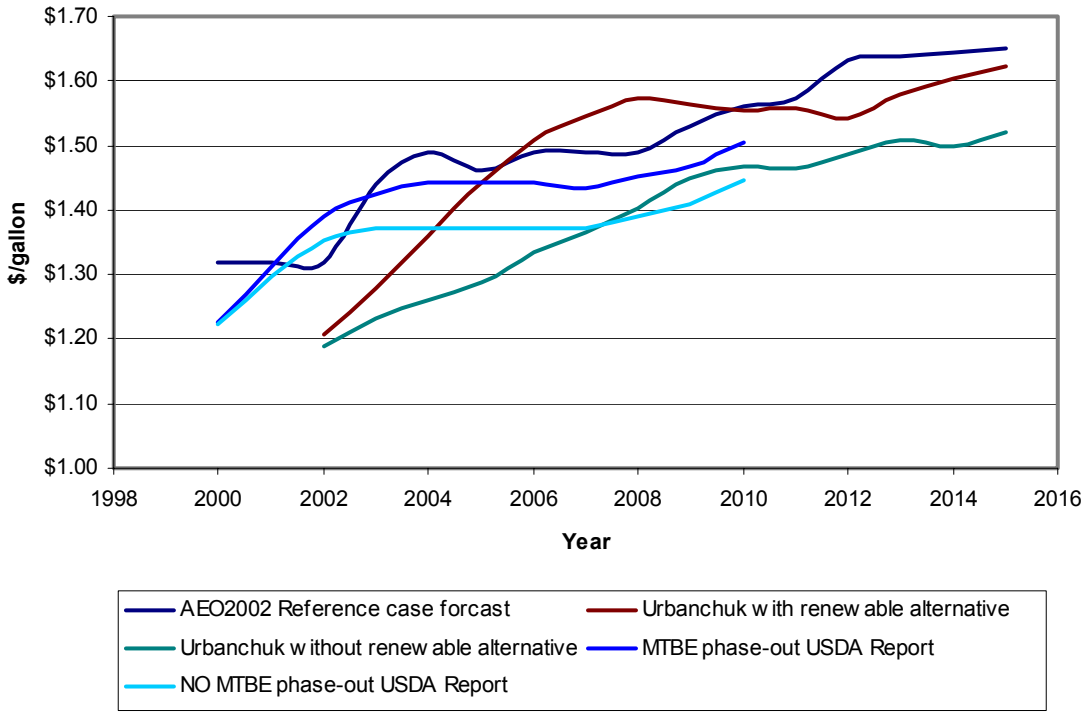
The phase out of MTBE, whether implemented at the federal level or on a state-by-state basis, is expected to drive the expansion of the U.S. ethanol industry to 3.0 – 3.6 billion gallons per year by the end of 2006. The proposed Renewable Fuels Standard also requires expanded ethanol usage, but the impacts of the RFS (if MTBE phase out continues) will really be felt on the period 2007 –2012. The RFS mandates steadily increasing levels of renewable fuels in the U.S.

transportation fuel pool, starting in 2004, reaching 5 billion gallons per year by 2012. Since ethanol and biodiesel are the only commercially available renewable fuels, the RFS, if implemented, will require a 300% increase in U.S. ethanol production over 2001 levels by 2012.

Impacts on Ethanol Prices

There is a strong consensus among analysts that U.S. ethanol prices will trend up sharply in the next decade, reaching $1.45- 1.50 per gallon in most projections by the 2006 – 2008 time period if MTBE is phased out and the RFS is implemented (figure 3 shows

Figure 3: Ethanol Price Projection 2003 – 2012
Under Different Public Policy Assumptions



projected prices under a variety of energy policy related scenarios). This price rise is due in part to scarcity as the ethanol industry adds new plants to meet rising demand and partly to upward pressures on grain prices from rising industrial and food processing demand.

Impacts on Corn Demand and Prices

The production of 5 billion gallons of ethanol, even at the optimistic conversion rate of 3.0 gallons of ethanol per bushel of corn, would require more than 1.6 billion bushels of corn -- 920 million bushels more than the ethanol industry requires today. The USDA has projected that U.S. corn production will rise by more than 1.77 billion bushels during the period 2001/02 – 2011/12, but that existing stocks would be drawn down sharply to help meet the total domestic and export demand. Even the most optimistic estimates see corn prices rising from $2.10 – 2.20/bushel

today to $2.60 – $3.00 within ten years, due in large part to rising demand for ethanol production.

Impacts on the Availability and Price for DDG

Distillers Dried Grain (DDG) is a co-product of the dry mill ethanol production process, used primarily today as cattle feed. Typically, each bushel of corn processed in a dry mill produces 17 pounds of DDG along with 2.5 – 2.7 gallons of ethanol. DDG sales are a significant revenue stream for most dry mills. Increasing U.S. corn-based ethanol production to 5 billion gallons per year by 2012 will mean an increase in DDG production from the current 2 million tons per year to more than 4.5 million tons per year. There is great uncertainty about the ability of the cattle feed market to absorb this much DDG without serious price erosions. Many dry mills are looking for ways to increase the protein value of their DDG in order to sell into other animal feed segments, such as swine and poultry feeding.

Impacts on Cellulosic Ethanol Development and Commercialization

The potential dramatic changes in the U.S. market for ethanol are expected to have mostly positive affects on the economic viability and pace of the commercialization of technology for converting cellulosic biomass to ethanol. The great uncertainty for cellulosic ethanol is how large the future U.S. market for ethanol as a blending stock for gasoline will be and how much of that overall market will be taken by the rapid expansion of grain-based ethanol production before cellulosic ethanol production technology is ready for commercialization. If U.S. grain-based ethanol production capacity reaches 5 – 6 billion gallons per year by 2010 – 2012, the question is: how much more market will there be for cellulosic ethanol unless it is significantly less expensive than grain-based ethanol so that it can capture market share by price alone?

The proposed phase out of MTBE by itself will put sharp upward pressure on grain-based ethanol prices in the period 2003 – 2006 while new ethanol production capacity is being built. Ethanol prices are projected to reach $1.40 – 1.50 by 2006, which is far above the market prices previously required to make ethanol from cellulosic biomass profitable. The Renewable Fuels Standard mandate is projected to keep ethanol prices above $1.40 for the remainder of the decade, since it will require the addition of production capacity equal to 8 to 10 large (40 million gallon/year) dry mills each year during the period 2008 - 2012. Ethanol prices are projected by several analysts to reach $1.50/gallon by the 2008 – 2010 period, even under relatively modest assumptions for key macroeconomic variables like economic growth and world petroleum prices.

The higher predicted market prices for ethanol and corn will make the business case for cellulosic ethanol much more attractive throughout the whole period 2004 –2012. This should accelerate investor interest in rapid commercialization of cellulosic biomass conversion technologies. Higher product prices will encourage investment in the near-term, rather than investors waiting until integrated pretreatment and conversion systems are optimized, until cellulase manufacturers reach all of their price targets, and until robust micro-organisms are developed that can convert four or five of the C5 and C6 sugars in the cellulose and hemi-cellulose fractions of biomass into ethanol.

High ethanol prices, rising corn prices and surging DDG production may also encourage grain ethanol producers to experiment in the near-term with the addition of significant cellulosic biomass conversion trains at existing or new dry mill facilities, using DDG as the feedstock. Extracting the cellulosic and hemi-cellulosic fractions from the DDG should significantly upgrade the protein content and food value of the resulting animal feed, making it more valuable and suitable for market segments such as poultry and swine feeding.

Similarly, wet millers may want to co-locate a small cellulosic biomass production facility at an existing ethanol plant, using feedstocks such as corn fiber or soy hulls to produce additional ethanol. Such a facility should be much less expensive to construct than a stand-alone cellulosic conversion plant, since it can use existing plant components for feedstock handling, distillation, and fuel storage. Feeding trials of the new corn fiber or soy hull-based animal feed will also be important to determine the economic value of the new animal feed and what market segments it might service.

There is one provision of the proposed 2002 Energy bill, **the cellulosic biomass ethanol incentive**, that, coupled with the expected glut of DDG that the grain-based ethanol production plant boom may create, may well trigger the first cellulosic ethanol additions to existing or new grain ethanol plants. The current Senate bills allows cellulosic ethanol 1.5 times the credits of grain-based ethanol in the proposed RFS trading system. Existing grain-based dry mill ethanol plants may well find it profitable to install cellulosic ethanol pretreatment and fermentation trains at existing or new plants to remove the cellulosic and hemicellulosic fraction of their DDG and convert it to alcohol. Similarly, wet mills could convert their existing corn fiber or soy hulls to "cellulosic ethanol" by adding pretreatment and fermentation trains. In the case of either dry mills or wet mills, the capital cost/gallon of the cellulosic ethanol systems would be considerable less than a dedicated cellulosic ethanol plant because they could make use of existing components, such as the feedstock handling system, distillation columns and transportation infrastructure. The feedstocks already located in the plant and would be relatively low value.

The key uncertainty in all these scenarios is the future price of DDG or corn fiber, given the major projected supply increase, and how the market price of DDG or corn fiber would be affected by removal of the hemicellulosic ands cellulosic fractions to create an animal feed with protein value high enough to enter new markets (poultry, swine) and compete against premium products like soy meal and corn gluten. If the market value of new upgraded DDG is high enough, then the installation of cellulosic pretreatment and fermentation trains might be worthwhile at wet mills just for the DDG treatment.

Co-Location Studies

In support of the Sugar Platform, NREL worked with two sub-contractors to look at the feasibility and economic viability of co-locating a cellulosic ethanol plant with a current or planned coal-fired power plant. The studies looked at two power plants in the Mid-West and one in New England to determine such key variables as the feedstock availability and cost, the impacts of the co-location on key ethanol plant capital and operating costs, proforma and economic analysis of required investments, any substantial environmental and social impacts, and markets for the plant's ethanol production. At all three sites, significant amounts of corn

stover were available for ethanol production, at delivered costs from $33 – 38/bone dry ton. The available corn stover at the three sites would support an ethanol plant ranging from 20 million gallons per year in upstate New York to more than 70 million gallons/year at a proposed power plant site in Nebraska.

The site-specific studies found that the internal rate of return (IRR) for two of the sites were quite reasonable – 18 – 23%/year or better – for larger size plants (50 – 70 million gallons/year) or when the proposed ethanol plant could make use of some of the coal-fired power plant's existing infrastructure. Sensitivity analyses revealed that the IRRs for the sites studied were quite sensitive to a number of factors, including: the price of the corn stover feedstock, the ethanol yield (in gallons/bone dry ton of feedstock), the sales price of the ethanol, and the percentage of equity investment in the plant. In general, delivered corn stover feedstock costs in the $25.00 – 30.00/ton range greatly increased the profitability of the proposed ethanol plant, as did ethanol selling prices above $1.25/gallon. The IRR of proposed co-located ethanol plants also increased sharply when the proposed equity investment dropped below 60% of the total project costs.

Building Support Networks for Emerging Biorefineries

A number of firms active in the food, fiber, fuels, and biotechnology fields are actively investigating the possibility of launching new research programs or business practices in biomass and biomass-based biorefineries. For firms or research groups entering the biomass field for the first time, the potential obstacles created by biomass analysis can appear to be formidable. The problems fall easily into four categories:

1) Biomass feedstocks are much more complex than simple starches or even most petroleum-based feedstocks and therefore more difficult to analyze accurately. Many firms and even national laboratories have found biomass analytic techniques difficult to execute consistently and reproducibly. While there are standard analytic protocols, there are many "tricks of the trade" that experienced scientists and technicians learn only with years of practice.

2) The cost to complete the required wet chemistry and analysis for a single biomass sample can run $800 to $3,000, depending on the feedstock and the number of components in the required analysis. The high cost of wet chemistry analysis is unacceptable for firms that are scanning hundreds or thousands of biomass samples looking for particularly characteristics, traits, or compositions.

3) More importantly, traditional wet chemistry is involved and time-consuming, with an analytic series for a single sample taking 2-4 weeks. The slow pace of traditional biomass wet chemistry analysis is simply unacceptable for firms in fast changing industries (such as biotechnology) or in plant genetics experiments where real time feedback is needed from field data collection.

4) Cutting edge biomass analytic equipment (particularly Near IR or NIR systems) is expensive to buy and calibrate – typically $35,000 – 85,000 for one systems depending upon configuration and attachments. Analyzing the output of this equipment also requires

the use of complex software packages. Firms would like to be able to compare and contrast hardware/software combinations to find the ones that best suits their needs and budgets. Once they have made a choice, they want to bring their staff up to speed rapidly on the equipment operation and on software utilization.

Rapid Analysis can provide a way around these high analytic costs and time delays. Once the analytic databases are created and the multivariate analysis (MVA) equations built, a sample can be analyzed in a matter of seconds at a cost of under $10.00. Hundreds of samples can be run in 1 – 2 days. If needed, real-time on-line or in-line data collection and analysis can be integrated into process control systems to insure production quality.

Firms and research organizations are increasingly turning to NREL's Biomass Analysis team for solutions to all four types of problems listed above. NREL scientists have been working on the analysis of all types biomass feedstocks for more than 25 years. We have created standard operating procedures, shortcuts, and an invaluable reservoir of practical knowledge on what works and what does not for particular types of biomass feedstocks. We are familiar with all the available equipment and software and work constantly with the manufacturers to add new capabilities and features. This knowledge and experience has real value and firms have expressed a willingness to pay to gain access to it.

Based on industry request, NREL is considering the development of a new industrially-led consortium that we are tentatively calling the Biomass Rapid Analysis Network or BRAN. While the activities of the BRAN will be determined by the Board of Directors, services that have been indicated as high priority by potential industrial participants include:

- 2 and 5 day training programs;
- Development of standard data collection and analysis protocols;
- Creation of new MVA equations
- Sample preparation;
- data clearinghouse for BRAN members;
- software testing; and
- Equipment testing.

How this proposed organization will be structured will be subject of detailed discussions with interested industrial and research partners.

Recommendations for Future Sugar Platform Partnership Development Activities:

Sugar Platform Partnership development will continue to play a major role in meeting DOE/OBP goals of:

- Dramatically reducing or even ending dependence on foreign oil
- Creating the new domestic bioindustry, and
- Creating cost-competitive fuels and products from integrated sugar biorefineries.

Industrial partners will assist in the needed cost reductions and technology scale-ups in a number of key ways:

- Locating and securing low-cost feedstocks (some of them captive residue streams within existing processing plants) for the initial technology demonstration plants
- Finding co-location opportunities that will reduce the required capital costs for demonstration plants
- Developing high value co-products from the sugar streams that will increase the economic viability of the planned biorefinery
- Finding new markets for existing Sugar Platform products and co-products